THE DON VALLEY INTERCEPTING SEWER

Richard Marshall
0742 734459
Adam Moran
0742 735842
0742 735005 (FAX)

DBS - Sheffield City Council
Drainage & Bridges Division
2-10 Carbrook Hall Road
SHEFFIELD
S9 2DB

1 BACKGROUND

1.1 The Don Valley Intercepting Sewer (DVIS) is a spine of trunk sewers and branches, mainly constructed by tunnelling at depths of around 20-25m. The finished diameters range between 1.7m and 5.25m. The total length of tunnel will be about 18,600m and there will be approximately 100 major shafts and chambers, as well as several hundred metres of large diameter open cut pipework and associated manholes.

1.2 The DVIS is just one part of an overall strategy designed to:- a) decimate the volumes of combined sewer overflow (CSO) spillage to the Rivers Don, Sheaf and Loxley and the Porter Brook in Sheffield, b) provide a means of diverting flows from the existing high level trunk sewers, allowing full renovation to take place and c) reduce the surcharging of the existing sewers and also the risk of flooding.

1.3 The hydraulic modelling of the City's sewers began in the late 1960s with data sheets being sent off to be converted to punched cards and run on an outside agency's mainframe TRRL package. Since then, the sophistication of the modelling has increased steadily as follows:

late 60s	TRRL on external mainframe
early 70s	TRRL on Council's mainframe
late 70s.	In house TRRL on HP desktop
early 80s	New in house TRRL on micro
mid 80s	WASSP on micro
late 80s	WALLRUS on micro
early 90s	Extended DOS WALLRUS

1.4 It is comforting to observe that as the power of the hardware and software has increased steadily over the years and the volume of input data has increased almost at the same rate, the results have remained more or less the same. In other words, the first phase of the DVIS, which was designed in the mid 1970s and is still not fully utilised, is effectively the same as would be designed today with the benefits of flow surveys, powerful computers, WALLRUS etc..

1.5 One point of particular interest is the change in perceived mode of operation of the new system. Originally, the new sewer in the Lower Don Valley, whose catchment was heavily industrialised and which was designed for nearly 100% run off, was simply sized to take about 50% of the dry weather flow and all of the storm flow from a theoretical 2 hour storm with a 2 year return period. (Very little, probably nothing, was known about areal reduction factors, summer/winter profiles etc. in those far off days). The vast majority of this storm flow would then have been spilled at a simple overflow at the Blackburn Meadows STW. Today, the area of industry and consequently the storm run-off has decreased drastically. At the same time, the desire to retain as much flow as possible in the high level sewers in order to minimise pumping costs and also the need to remove all but a minimum of well controlled storm discharge from the rivers have resulted in the DVIS becoming almost a linear off-line storm tank with multiple inlets.

2 PRESENT SITUATION

2.1 DVIS Contracts 1, 2 and 3, between the STW and the City Centre have been completed and commissioned. Contract 4, including a 500m extension and two lengths of tunnel into the Sheaf Valley, are nearing completion (end of 1991).

2.2 Contact 5A, which takes the DVIS to the junction with the proposed Loxley Valley Trunk Sewer, is already underway, being constructed by the same Contractor that undertook Contracts 3 and 4. Contract 5B, which completes the DVIS, has received technical approval from Yorkshire Water and is programmed to be constructed straight after Contract 5A.

2.3 The schemes for renovating the high level trunk sewers and abandoning the CSOs have been completed for the majority of the sewer network in the Lower Don Valley. These schemes generally lag behind the main tunnel schemes due to the fact that the tunnels are required for flow diversion. However, in order to speed up the realisation of the benefits, DVIS Contract 5 does include the abandonment of the existing CSOs along its route.

3 FLOW SURVEY & VERIFICATION

3.1 The DVIS Contract 5 catchment takes flow input from a number of other large catchments. It was not considered feasible at the time to carry out a flow survey of the total area contributing flow so it was decided that the survey should concentrate on the trunk sewers in the valley bottoms. The remainder of the DVIS Contract 5 catchment and the other contributing areas would be the subject of future Drainage Area Plans.

3.2 Historic data and local knowledge predicted that flat gradients, high surcharge and siltation were all features of the trunk sewers and it was suspected that flow reversal would be found under surcharge conditions at two or more locations.

3.3 The survey was undertaken between November 1989 and January 1990 and was successful in terms of logging sufficient usable events within the allotted period.

3.4 Data logging was just about acceptable, with the usual crop of ragged and greased transducers and, unusually, two out of eight rain gauges malfunctioning by only recording tips to one side, i.e. only recording half of the rain.

3.5 The verification process was carried out by staff in the Council's Main Drainage Section and followed the usual line of trial and error, hard slog and occasional divine inspiration. It was completed by mid 1990.

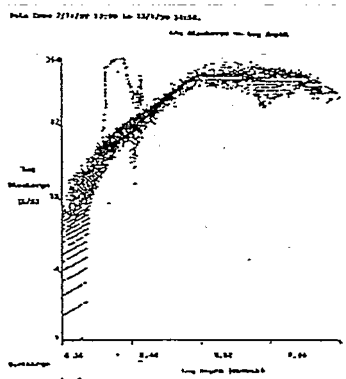
3.6 One point worthy of emphasis is that the whole of the survey data and interrogation software was available for this in-house verification. This proved to be essential and it would have been impossible to verify with only extracted data relating to a handful of storms.

3.7 Two of the more interesting features of the verification are discussed below.

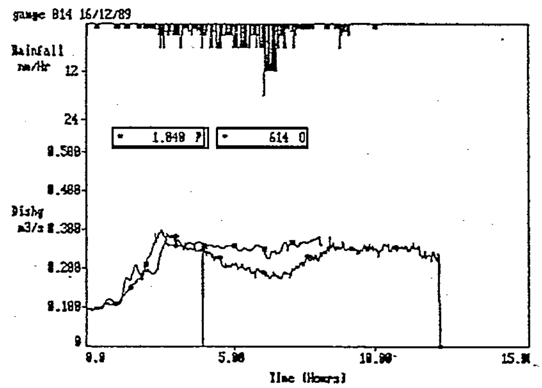
4 REVERSE FLOW

4.1 At the upper end of the catchment, near to the Hillsborough football ground, there is an overflow which is throttled by a long length of flat 3'x2' sewer in Penistone Road. The outfall from the Loxley Valley system is also a flat 3'x2' sewer which joins the Penistone Road section at the downstream end of the throttling length.

4.2 This configuration has the result that both of these lengths of sewer surcharge during virtually any rainfall. This is illustrated very well by the scattergraph for the whole of the survey period for the monitor site in the middle of the Penistone Road length.



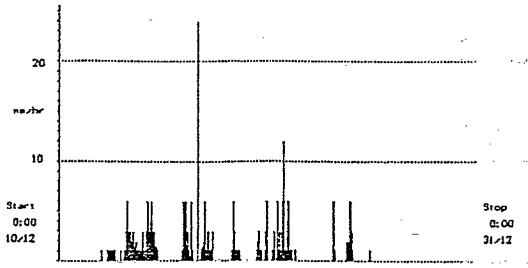
4.3 The higher the surcharge levels in Penistone Road, due to the backing up effect of the flow from the Loxley Valley outfall sewers, the less is the hydraulic gradient available for the pass on flow from the overflow and so the greater the spill to the River Don. At the peak of just about every storm, the pass on flow has an appreciable dip. This phenomenon was observed many times during the flow survey and is also clearly visible in the verified model.



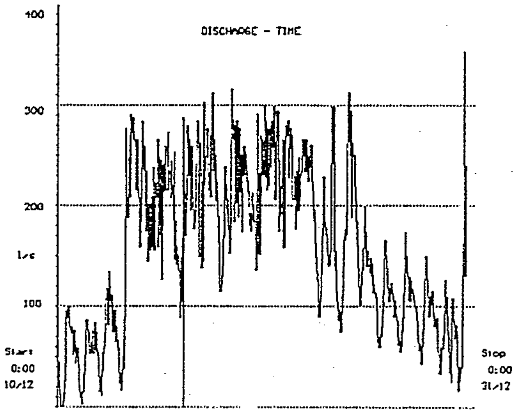
4.4 When the model is tested with design storms, surcharge builds to such a level that flow reverses upstream to the overflow. Such an event was apparently recorded during the flow survey when, at the peak of a storm, about 1,750l/s was recorded spilling to the river when only 1,500l/s was recorded entering the overflow by the normal means. The implication is that 250l/s reversed into the overflow from downstream.

5 MODELLING INFILTRATION

5.1 Within the survey, there was a two week period with an unusually large volume of rain without any exceptional intensity.

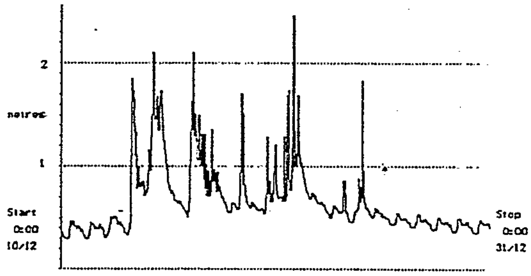


5.2 This caused a very significant amount of infiltration in the main sewers which took many days to subside. The following chart illustrates this effect at the gauge point within the flat length discussed in section 4 above.



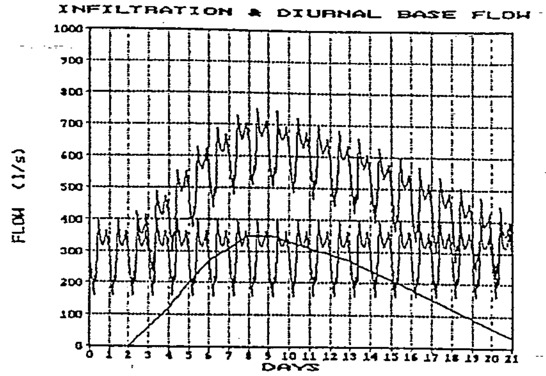
5.3 It was felt that such copious infiltration would have a significant effect on the volumes spilled at the many overflows on the system and so this long period of rain was simulated to determine the volumes likely to have been overflowed.

5.4 Infiltration for the whole catchment was assessed by inspection of the height recorded at the downstream end of the catchment and converting the excess height to excess flow. (Flow could not be obtained directly as the velocity sensor was very prone to ragging).



5.5 Using infiltration, the simulation of around 1200 pipes over 21 days was run over a weekend and produced very satisfactory results. The simulated total volume spilled to the river during this period was 263,000m^3. This is 35% of the annual total of 750,000m^3 which had been predicted using time series rainfall and the obvious implication is that the time series may underestimate spillage from CSOs in areas where infiltration is a problem.

5.6 The derived infiltration was combined with a 21 day dry weather flow file (one hour increments) using a spreadsheet. The dry weather flow file had been produced using the technique described in the paper presented at the Autumn 1990 WaPUG.



6 D.V.I.S. Contract 5

6.1 Don Valley Sewer Contract 5 is a £17.7M scheme which will be constructed in two phases. It mainly consists of 3.85km of tunnelled sewer of 1.72m & 2.65m finished diameters. There will also be three branch sewers in tunnel and one in open cut, associated shafts, bifurcation chambers, pipelines, manholes and two new overflow structures.

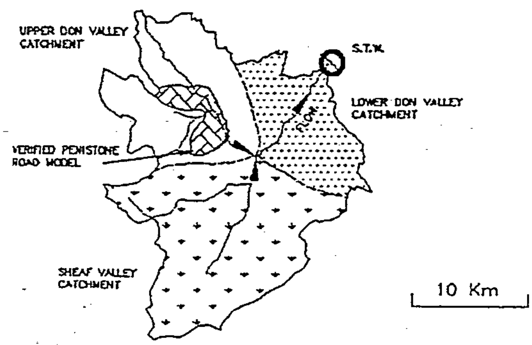
6.2 The abandonment of fifteen existing overflows will be enabled, and 2.5km of existing trunk sewer will be relieved and made accessible for renovation.

7 DVIS Contract 5 - Model Building

7.1 In order to design a scheme of this size and complexity it was necessary to:-

a) build a detailed model of the existing sewerage system of Sheffield's Upper Don Valley Catchment and

b) model the flows of both the Lower Don Valley and Sheaf Valley Catchments.



7.2 The detailed model of the Upper Don Valley was built by attaching a number of partially verified catchments to the fully verified Penistone Road model.

7.3 The detailed model extends down to the City centre where the flows from the Upper Don Valley and the Sheaf Valley catchments outfall into the Lower Don Valley catchment.

7.4 These three large catchments were each assumed to be responsible for a third of all flows reaching the S.T.W. and account for one third the capacity of the existing tunnel sewer between the City centre and the S.T.W.. This approximation enabled the effects of the outfall of the Upper Don Valley catchment to be modelled realistically for a further 8km and take account of the action of the wet well pumps at the S.T.W..

7.5 At this stage it was possible to simulate design storms on the existing sewer network in order to evaluate the flows which would have to be turned in to the proposed tunnel. This allowed a provisional sizing of the diameters of the tunnel using Colebrook-White formulae, and enabled a model of the proposed tunnel to be built and appended to the larger model.

7.6 The model now consists of 1395 pipe lengths and 48 ancillaries. It has a simulation time:run time ratio of 7:1 on a 486/25 MHz computer.

8 DVIS Contract 5 - Model Running

8.1 A series of design storms of varying lengths were run to ascertain the critical length of storm for:

a) the high level sewers - in order to locate and evaluate the number of bifurcation chambers.

b) the proposed tunnel - in order to determine its dimensions.

8.2 Time Series Rainfall was simulated to analyse the design of the two new overflows and ensure that they fulfilled the N.R.A.'s criteria for discharge.

9 DVIS Contract 5 - Model Problems

9.1 Building Stage - As each sub-model was added to the larger model it was necessary to check whether the same pipe and ancillary labels had been duplicated. This became a problem as there are only 999 unique pipe reference labels available.

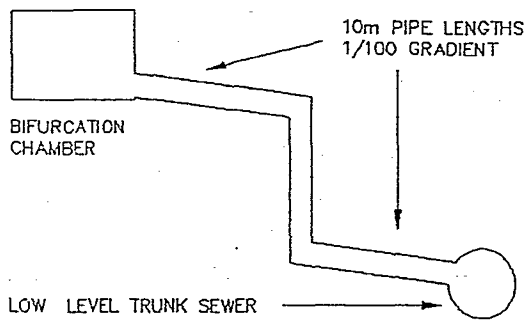
9.2 Simulation Part 1 - A paper file was compiled of "Fatal Error" messages and their solutions, not all of which were immediately obvious

e.g.
Checking Pipe 860.160
Fatal Error : 64
Branch number 860 has already appeared

Solution : This is a misleading description. In the line prior to 860.160 an on-line tank record (type 9) was incomplete.

9.3 Simulation Part 2

a) Generation of flows - This mainly occurred at the bifurcation chambers, and was overcome finally by modelling each chamber and transfer arrangement as below.



Even then, it was necessary after each simulation, to check that the volume of water spilled at each bifurcation balanced with the volume of water in the tunnel.

b) Model instabilities - The model invariably became unstable in the tunnel at the point at which the flow condition changed from normal to surcharged. This instability, once established, magnified and transmitted down the tunnel. This problem was eventually overcome by a hit or miss method of placing backwater indicators on various pipe lengths in the tunnel.

c) Batch Running Operation - Problems occurred here due to the large size of the Gauge Point file which occupied 28 screen pages. The program stopped after loading the first 11 pages as it expected F5 to be pressed for continuation. By manually text editing the RUN*.S2 file (as shown below) the Batch operation could be used.

Original File
.....................DON.GGS #5#5#7
Amended File
.....................DON.GGS #5#5#5#5#7

9.4 Time Series Rainfall - Time Series storms are short in comparison to the tunnel sewer's critical duration of some 3½ hours. This raised the question of the validity of the spills predicted for the two new overflows using these isolated storm events. A 21 day simulation, using the actual rainfall described above, was run on the model, and the results were used to calibrate the T.S.R.

Paper 5: Verification And Modelling Of The Don Valley Interceptor (R Marshall - Sheffield City Council)

D Walters, M W Barber & Co : I was surprised at the use of bifurcations in the system. Why was this?

Ans : The original plan was to keep half of the dry weather flow in the high level system to reduce the costs of pumping the flows back up to treatment. This was done with bifurcations. Now the plan is to keep all of the dry weather flow in the top system, and so the bifurcations have been changed to overflows. The design criteria is to have no surcharge in the top system in a 2 year storm. The interceptor sewer acts to provide storage for storm flows, and if the storage is insufficient that it spills over an overflow fitted with screens as the treatment works.

....

D Balmforth, Sheffield City Polytechnic : How was the 21 day simulation run used to adjust the result from the time series rainfall?

Ans : A Simple multiplication factor was used assuming that spills will be roughly equal throughout the year.